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INTRODUCTION

The passage of cyclone Xaver on 5-6th December 2013 led to severe floods and to substantial coastal erosion along large parts of the Danish and German coasts. Water levels of nearly 2 meters are the highest on record a.o. at the Hornbaek and Copenhagen tide gauges (TG) (1890-2015). The extremity of the event accentuates the need for robust and updated extreme value statistics and it questions their current use e.g. for design, planning and adaptation purposes. We investigate the coastal impact and implications on coastal management and design water levels for selected Danish locations affected by Xaver.

METHODS

Extreme value statistics for selected tide gauge series are recalculated to include the Xaver event. In addition, in-situ and satellite waves and sea level measurements are included to evaluate the event and to explain its impact. From this, post-Xaver changes in coastal management practices and in the public perception of storm surges versus climate change impacts are investigated for three Danish case areas.

RESULTS

A significant increase of 5-10% in the statistics of a 100 year return level in the long TG series is found at Hornbaek and Copenhagen, whereas in shorter series like the Roskilde TG a statistical assessment of the event is difficult. For Copenhagen, the inclusion of events predating TG data may increase a 100 year event by up to 25%. However, the validation and evaluation of water levels from these past events is difficult, too, and caution is advocated when attempting to construct extreme statistics based on historic evidence due to a very large uncertainty in the data. In addition to the extreme water levels, also recorded by Cryosat 2 satellite imagery, Figure 1, the duration of the Xaver event (Hornbaek TG: max. water level 1.96 m DVR90; >1.50m DVR90 for 16.5 hours) and wave conditions (Hs=3.5m at 8m depth) off the north coast of the island of Sealand intensified the impact (Sorensen et al., 2016).

DISCUSSION

The implication of Xaver on coastal management varies between the investigated areas due to the experienced flooding and erosion, historic development, politics, economy, pre-Xaver design measures etc.

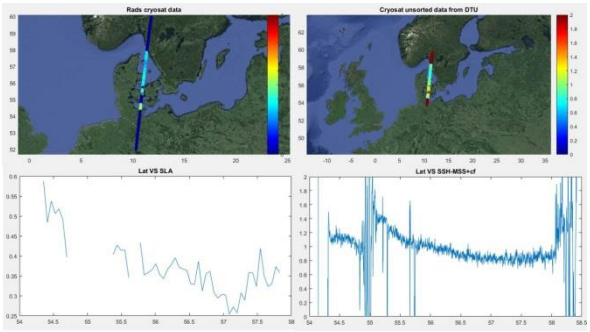

Figure 1 - Storm Surge Xaver observed by Cryosat-2 along the track down through Kattegat and Storebaelt in Denmark relative to mean sea level. Left is RD-SAR 1-Hz Cryosat-2 data (Cryosat-2 treated as conventional altimetry) and right is 20 Hz Cryosat-2 SAR altimetry processed using SAMOSA-3.

In the narrow Roskilde Fiord, which experienced the most severe floods of inhabited areas, the neglect of past events and insufficient protection measures are now being dealt with in specific projects and visions for the future. Still, the extremity of Xaver puzzles decision-makers and consultants in deciding upon future design water levels. On North Sealand the experienced erosion led to municipal collaboration along the entire coastline to provide more holistic solutions for coastal protection that involves sand nourishments and the restoration of recreational values. In Copenhagen, where extensive flooding was avoided by about 0.1 m in extreme water levels, the event led to delay of planned developments and to an enhanced focus on the need for robust design measures. This includes also the evaluation and integration of past events (pre-dating tide gauge series) for use in extreme value statistics and in planning.

CONCLUSIONS

There is a strong need for dissemination of extreme value statistics, their validity and potential use in planning and decision making. Furthermore, statistics' updates should be performed following very severe events.

REFERENCES

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